(12) UK Patent Application (19) GB (11) 2 156 824 A

(43) Application published 16 Oct 1985

(21) Application No 8507703

(22) Date of filing 25 Mar 1985

(30) Priority data
(31) 84/056676 (32) 24 Mar 1984 (33) JP
84/137000 2 Jul 1984
84/192364 13 Sep 1984

(71) Applicant
Meishintoryo Co Ltd (Japan),
1-27-6 Taishibashi, Asahi-ku, Osaka 535, Japan

(72) Inventors
Tatsumi Shiotsu
Toshio Adachi

(74) Agent and/or Address for Service
W P Thompson & Co,
Coopers Building, Church Street, Liverpool L1 3AB

(51) INT CL^4
C08K 3/32 A61K 6/08

(52) Domestic classification
C3J CH
C3W 209
U1S 1028 1034 1037 1382 C3J

(56) Documents cited
US 4288355

(58) Field of search
C3J
C3V

(54) Surgical cements

(57) A surgical cement comprises:
a) self-hardening α-tricalcium phosphate powder or self-hardening amorphous tricalcium phosphate powder;
b) a surgically acceptable water-soluble poly(carboxylic acid); and
c) water.
The setting rate of the cement may be controlled by addition of an organic acid, e.g. glycolic or citric acid.

GB 2 156 824 A

SPECIFICATION

Surgical cements and method for preparation thereof

The present invention relates to a surgical cement, more particularly the invention pertains to a surgical cement containing α-tricalcium phosphate and/or amorphous tricalcium phosphate as the principal component and a method for preparing the same.

To date, many materials applicable to the living body such as plastics materials or various kinds of metals, for example, gold, silver, alloys of palladium, Ni-Cr alloys, Co-Cr alloys, amalgam, stainless steel, titanium alloys have been proposed and they have been used in many fields such as orthopaedics and dentistry. These materials have many applications for tooth crowns, or the root of a tooth, and further they have been tried for use in artificial bones, artificial joints or the like. They have a high reliability in their mechanical strength and are capable of precision processing, but they have various undesirable characteristics such as dissolution, corrosion, deterioration due to the severe environmental conditions in the living body and they suffer from fatigue during the long-term service and accompany a foreign substance-forming reaction, (for instance the formation of secondary caries).

Then, ceramics materials having a relatively good affinity for living tissues have recently been paid great attention.

For example, artificial bones, artificial joints and the artificial root of a tooth composed of Al_2O_3 as single crystal, or as a sintered body thereof, or those constituted by hydroxyapatite have been proposed.

However, these implant materials have the disadvantages that they are too hard and fragile, these being common to the ceramics. Many problems to be solved still remain in order to adopt them as the material for artificial bones and the root of a tooth.

A cement in which orthophosphoric acid solution is conventionally used as the setting solution, is known in the field of surgical cement. For instance, zinc phosphate cement is obtained by kneading zinc oxide with about 70% aqueous orthophosphoric acid solution and silicate cement is used in the form of a product of kneaded silicate glass with aqueous phoshoric acid solution. However, these cements are highly acidic due to the phosphoric acid used and accordingly, they cause pulpal injury effects and moreover they have insufficient adhesion with teeth.

U.S. Patent Nos. 3,655,605, 3,741,926, 3,751,391 and 3,804,794 propose zinc oxide-polycarboxylate cement in which aqueous poly(carboxylic acid) solution having a weak pulpal injury is used instead of the aqueous orthophosphoric acid solution.

In addition, ionomer cements have been developed in order to modify the compressive strength of cements and in said ionomer cements fluoroaluminosilicate is used in place of zinc oxide, which is set with an aqueous solution of poly(carboxylic acid) (see, for instance, U.S. Patent Nos. 3,814,717, 4,016,124, 4,089,830 and British Patent No. 1,316,129). However, the ingredients used in these cements differ chemically from those of the teeth and bones and therefore, many problems to be overcome still remain, for example that these are less compatible with living tissues, that they irritate pulpal tissues and that they penetrate into the dentinal tubule and the like.

Moreover, in order to adjust the setting speed of carboxylate cements composed of zinc oxide and poly(carboxylic acid), there have been proposed, for example, a composition which is prepared from the carboxylate cement by adding, as a filler, a small amount of calcium phosphate powder thereto (see U.S. Patent Nos. 3,655,605, 3,751,391 and 4,288,355); and a cement composition obtained by mixing hydroxyapatite as principal component with an inorganic powder, such as ZnO, CaO, Al_2O_3, $Ca_3(PO_4)_2$, SiO_2 and poly(carboxylic acid) (see, for example, Japanese Patent Laid-Open Appln. No. 83605/1983).

However, such surgical cements do not satisfy the requirements for compatibility with living tissues and for compressive strength at the same time.

The materials applied to the living body are always in contact with the living tissues and are subjected to long-term service. Therefore, they must be safe, that is to say, they must not have harmful effects on the living body such as tumorigenesis and also they must not irritate the tissues around the part where the cement is filled or applied. In addition, they should have a good compatibility with the living cells, i.e., a good adhesion to them and a self-ossification, in other words, the assimilation between neonatal bones and the surface of the material.

Under these circumstances, there has been a strong need for the development of materials for living organisms which include components similar to principal components of the teeth or bones and which have an excellent compressive strength.

According to the present invention there is provided a surgical cement comprising:

a) a component (A) composed of at least one member selected from the group consisting of self-hardening α-tricalcium phosphate powder and self-hardening amorphous tricalcium phosphate powder;

b) a component (B) of surgically acceptable water-soluble poly(carboxylic acid); and
c) water.

According to the present invention there is further provided a process for preparing a surgical cement which comprises preparing a mixture by admixing (a) a component (A) of at least one member selected from the group consisting of self-hardening α-tricalcium phosphate powder and self-hardening amorphous tricalcium phosphate and (b) a component (B) of a powdered surgically acceptable water-soluble poly(carboxylic acid), and adding a desired amount of water, or by adding an aqueous solution of component (B) to component (A); then kneading the mixture thus obtained to convert the mixture to a fluidized or plastic state.

By means of this invention surgical cements can be provided which are applicable in the fields of medicine and dentistry, which have components quite similar to those of the teeth or bones of the living organisms, so that they do not cause a foreign substance-formation reaction and they are quite excellent in their compatibility with the living organism.

By means of this invention it is possible to provide a surgical cement which can be filled into root canals of teeth or into defects and vacant parts formed due to diseases or external factors.

It is also possible by means of this invention to provide a surgical cement applicable as a restorative material to repair the alveolar bone eroded by degeneration and as a filler for tooth and bone fissures which are formed due to external factors such as, for example, periodontosis and traffic accidents.

By means of this invention it is also possible to provide a surgical cement of a high compressive strength, which is also applicable to the case where a high strength is required immediately after filling.

It is further possible by means of this invention to provide a surgical cement, by which the structure and functions of injured parts and vacant parts (cavities) are repairable or restorable.

In the term "self-hardening α-tricalcium phosphate and/or self-hardening amorphous tricalcium phosphate" used in the surgical cement of this invention, the term "self-hardening" means that these phosphates react with surgically acceptable water-soluble poly(carboxylic acid), disclosed below in more detail, to set together.

In order to attain the objects of this invention, self-hardening α-tricalcium phosphate [α-$Ca_3(PO_{42}]$ powder and/or self-hardening amorphous tricalcium phosphate [$Ca_3(PO_4)_2 \cdot xH_2O$] powder must be used.

In general, said α-tricalcium phosphate may be prepared according to one of the following methods. For example, one method comprises heating dried calcium hydrogen phosphate dihydrate [$CaHPO_4 \cdot 2H_2O$], at a temperature of from about 300 to 500°C to form γ-calcium pyrophosphate (γ-$Ca_2P_2O_7$), then uniformly mixing equimolar amounts of γ-calcium pyrophosphate and calcium carbonate, calcining the mixture, after sufficiently drying, at a temperature of from 1,000 to 1,300°C, preferably around 1,200°C, for about one hour and finely pulverizing the calcined product to obtain powder having a particle size equal to or less than 100μm. Another method for preparing α-tricalcium phosphate [α-$Ca_3(PO_4)_2$] powder comprises uniformly mixing calcium hydrogen phosphate dihydrate and calcium carbonate at a molar ratio of 2:1, then calcining the mixture under the same conditions as disclosed above and pulverizing the calcined product according to the aforementioned manner.

The α-tricalcium phosphate powder thus obtained may be further processed according to the following procedures which comprise compressing the α-tricalcium phosphate powder, calcining the pressed powder at a temperature of from 1,200 to 1,500°C, preferably 1,200 to 1,300°C for at least one hour and then pulverizing the calcined product as in the case mentioned above, to form fine powder having a particle size distribution of 0.5 to 20 μm.

In addition, α-tricalcium phosphate may be prepared by compressing amorphous tricalcium phosphate under pressure and calcining and pulverizing according to the same procedure as mentioned above.

In the latter method, in which the calcination and the pulveriztion treatments are carried out twice, the first treatment is effected to form -tricalcium phosphate and the second treatment is carried out to improve density of the powder and to enhance the compressive strength. However, the product obtained by the first treatment may still be used in the surgical cement as the principal component thereof and provides satisfactory results.

Furthermore, if desired, there may be added to the cement 0.1 to 10% by weight, preferably 0.1 to 2% by weight of aluminium phosphate before the single calcination step or before the first or the second calcination and pulverization steps, in order to improve the compressive strength of the final surgical cement.

On the other hand, amorphous tricalcium phosphate may generally be obtained by a process which comprises reacting an aqueous solution of a calcium salt and an aqueous solution of phosphate, separating the product by filtration at a low temperature and drying it.

Calcium nitrate is the preferred calcium salt and ammonium phosphate is preferably used as the phosphate. The reaction is preferably carried out at a pH of from 10 to 12 and the reaction is similar to the known wet synthesis of calcium hydroxide apatite. After the completion of the

reaction, the processes such as the separation by filtration, drying and pulverization are carried out at a low temperature. This is an important condition for maintaining the calcium phosphate thus formed in the amorphous state without causing any crystallization.

In this method, it is, therefore, preferable to carry out the separation by filtration, drying and pulverization at a temperature of from − 10°C to + 10°C. In particular, the upper limit is critical in the process as this is required to maintain the reaction product in the amorphour state as mentioned above.

The drying operation may be, for example, lyophilization (freeze-drying).

Another essential component of the cement of the present invention is a surgically-acceptable water-soluble poly(carboxylic acid). All the known poly(carboxylic acids conventionally used in surgical cement, such as cement containing zinc oxide as the principal component or ionomer cement dislosed in U.S. Patent No. 4,089,830, may be used in the present invention without any difficulties.

The preferred poly(carboxylic acids) are those prepared by the homo-polymerization or co-polymerization of unsaturated aliphatic carboxylic acids and copolymerization of these acids with other unsaturated aliphatic monomers.

The poly(carboxylic acid) solution which is used in the preferred surgical cement according to the invention may be prepared by any of the customarily used polymerization techniques. For example, polymerization may be carried out in aqueous solution in the presence of ammonium persulphate and various chain transfer agents to give solutions containing up to about 30% of the polymer. This solution may then be concentrated, if necessary, to give a more viscous solution, or freeze-dried to give a solid particulate poly(carboxylic acid).

Various other acrylic monomers may be included in the polymerizing system to give carboxylic acid copolymers having modified properties, provided that the carboxylic acid copolymer is sufficiently soluble in water and reacts with a tricalcium phosphate powder in the required manner.

Particularly preferred poly(carboxylic acids) are (i) homopolymers of acrylic acid, or (ii) copolymers of (a) acrylic acid, preferably in an amount of 60 to 99.9% by weight, as the principal component and (b) preferably 0.1 to 40% by weight of at least one unsaturated monomer selected from the group consisting of itaconic acid, maleic acid, fumaric acid, methacrylic acid, aconitic acid, citraconic acid, glutaconic acid, mesaconic acid, tiglic acid and a lower alkylester thereof (the alkyl group having 1 to 5 carbon atoms), and a lower alkylester of acrylic acid (C_1 to C_5 alkyl).

The surgically acceptable water-soluble poly (carboxylic acid) useful in the surgical cement of the invention preferably has a viscosity-average molecular weight of from 2,000 to 200,000, more preferably from 5,000 to 150,000, when determined by the method of Sakamoto (Chem. Abstr., *58*, 13160C).

The poly(carboxylic acid) may be used in the form of powder or in the form of an aqueous solution having a concentration ranging from 10 to 60% by weight, preferably 25 to 55% by weight.

The preferred surgical cement according to the invention comprises (a) 23 to 75% by weight, most preferably 33 to 72% by weight of at least one member (component (A)) selected from the group consisting of self-hardening α-tricalcium phosphate and self-hardening amorphous tricalcium phosphate, (b) 2 to 46% by weight, most preferably 7 to 37% by weight of a poly(carboxylic acid) (component (B)) and (c) 10 to 69% by weight, most preferably 12 to 50% by weight of water.

When component (B) is used in the form of an aqueous solution having a concentration of 10 to 60% by weight, preferably 25 to 55% by weight, the ratio of component (A) to the aqueous solution of component (B) is from 0.3:1 to 3.0:1, preferably from 0.5:1 to 2.5:1.

Even if the poly(carboxylic acid) is used in aqueous solution, the respective components must be adjusted so that the amount thereof falls within the aforementioned range.

The surgical cement according to the invention is preferably adjusted so that the weight ratio of the surgically acceptable water-soluble poly(carboxylic acid) to the self-hardening α-tricalcium phosphate falls within the range of from 0.4 to 0.6 and that the weight ratio of water to the self-hardening α-tricalcium phosphate falls within the range of from 0.4 to 0.7, in particular when the surgical cement is used in applications in which high compressive strength is needed.

Furthermore, in the surgical cement of the invention, many other organic acids other than poly(carboxylic acid) may be included preferably in an amount up to 10% by weight, in order to control the setting speed during its application for repairing or restoring the tooth canals and so on.

In the case where the organic acid is used in the form of aqueous solution, the amount of water present in the aqueous solution of the organic acid is previously adjusted so that the total amount thereof falls within the range mentioned above.

As the organic acid which is preferably used in the surgical cement of the invention, there may be mentioned, for example, glycolic acid, glutamic acid, pantothenic acid, lactic acid,

tartaric acid, citric acid, malic acid, all of which may be used singly or as a mixture containing two or more of them.

Surgical cements can be obtained according to the invention, by combining α-tricalcium phosphate and/or amorphous tricalcium phosphate with poly(carboxylic acid), the cement being suitable for use as a root canal filling material, a lining cement, or as a restorative agent for use in alveolar bones, and having good compatibility with living tissues.

The invention will now be described in detail with reference to the accompanying Examples, which are purely illustrative. In the Examples, the terms "parts" and "%" are expressed as "parts by weight" and "% by weight" respectively.

Reference Example 1:
Preparation of α-tricalcium phosphate.

Calcium hydrogen phosphate dihydrate ($CaHPO_4 \cdot 2H_2O$) was calcined at 500°C for 2 hours to form γ-calcium pyrophosphate (γ-$Ca_2P_2O_7$). The resulting pyrophosphate was further calcined at 1,200°C for 2 hours after uniformly mixing with an equimolar amount of $CaCO_3$, and cooled rapidly. The product thus obtained was then pulverized and passed through a 300 mesh sieve to adjust the particle size distribution. According to X-ray diffraction,, the product is found to be α-tricalcium phosphate. This product is, hereunder, referred to as "α-TCP".

Reference Example 2:
Synthesis of amorphous tricalcium phosphate.

The reaction of 3l of 0.5 mol/l aqueous solution of calcium nitrate [$Ca(NO_3)_2$] with 2l of 0.5 mol/l aqueous solution of ammonium hydrogen phosphate [$(NH_4)_2HPO_4$] was carried out by mixing them under a nitrogen gas stream at a temperature equal to or less than 5°C, while adjusting the pH to 11 by the addition of aqueous ammonia to the solution.

The resulting precipitates were filtered off below 0°C and washed with aqueous ammonia and then lyophilized for 24 hours. The product thus obtained was pulverized to form powder having the particle size of less than 300 mesh. The X-ray diffraction pattern thereof simply shows a halo and no peak attributed to a crystal is observed. This product is hereunder referred to as "A-TCP".

Example 1

α-TCP and A-TCP synthesized in reference Examples 1 and 2 were kneaded with an aqueous poly(carboxylic acid) solution and, after 24 hours, the product was subjected to compressive strength measurement according to the method of JIS T-6602. The results obtained are shown in Table I. Copolymers of acrylic acid/itaconic acid (containing 15% of itaconic acid moiety, MW = 80,000 and 31,000) were used as the poly(carboxylic acid) in the example.

Table I.

	Aqueous poly(carboxylic acid) soln.			**Compressive strength
Powder	Mw*	concn.(%)	P/L	(kg/cm^2)
α-TCP	80,000	25	1.3	180
α-TCP	80,000	30	1.3	320
α-TCP	80,000	45	1.3	720
α-TCP	80,000	50	1.3	770
α-TCP	80,000	45	0.5	150
α-TCP	80,000	45	1.0	630
α-TCP	80,000	45	1.8	800
α-TCP	31.000	45	1.3	700
A-TCP	80,000	45	1.3	600

*viscosity- average molecular weight (hereunder, all of the molecular weight (MW) is expressed as viscosity-average molecular weight).

**the weight ratio of the powder to the solution.

As evident from the results listed in Table I, α-TCP and A-TCP show sufficient compressive strength to use as a root canal filling agent and surgical cement.

Example 2

The α-TCP obtained in reference Example 1 was mixed with polyacrylic acid powder and the mixture was kneaded in the presence of a desired amount of water.

Then the measurement of compressive strength on the resulting product was carried out according to the same procedure as in Example 1. The results obtained are shown in Table II. In this Example, the copolymer of acrylic acid/itaconic acid (containing 15% itaconic acid moiety; MW: 80,000) was used as the poly(carboxylic acid).

Table II.

Amount of α-TCP (g)	*Amount of poly(carboxylic acid) (g)*	*Amount of water (g)*	Compressive *strength (kg/cm^2)*
2	0.7	1.2	530
2	1.0	1.2	580
2	1.1	1.2	550

Example 3

The procedures of Example 1 were repeated, except that various poly(carboxylic acids) were used. The results of the compressive strength measurements are listed in Table III.

Table III.

poly(carboxylic acid) Composition	Mw	concn. (%)	P/L	Compressive strength (kg/cm^2)
Polyacrylic acid	5,000	40	1.0	120
Polyacrylic acid	30,000	40	1.0	350
acrylic acid/5% itaconic acid copolymer	66,000	40	1.3	680
acrylic acid/30% itaconic acid copolymer	30,000	40	1.3	690
acrylic acid/5% maleic acid copolymer	15,000	40	1.3	670
acrylic acid/10% fumaric acid copolymer	10,000	40	1.3	670

Example 4.

The setting solution obtained by adding 50% aqueous solution of an organic acid to an aqueous poly(carboxylic acid) solution was kneaded with α-TCP synthesized in reference Example 1. The compressive strength was measured on the resulting product in accordance with the procedure of Example 1. The results obtained are listed in Table IV. The aqueous poly(carboxylic acid) solution used was a 45% aqueous solution of acrylic acid/itaconic acid copolymer (containing 15% itaconic acid moiety; MW: 80,000).

Table IV.

Organic Acid Used.	Amount of the Organic acid soln. (%)	P/L	Compressive Strength (kg/cm^2)
glycolic acid	5	1.0	650
glycolic acid	10	1.0	670
glycolic acid	20	1.0	580
citric acid	5	1.0	680

The addition of organic acid makes it possible to reduce the setting time.

Example 5.

The powder of α-TCP obtained in reference Example 1 was pressed under a pressure of 500kg/cm² and 1,200kg/cm², in a mould to form a tablet and then the tablet was calcined at 1,200°C for 2 hours. The calcined tablet was finely pulverized and the powder was passed through the 300 mesh sieve. Using the powder thus produced, the procedures of Example 1 were repeated and the compressive strength of the product was determined and the results are shown in the following Table V. The aqueous poly(carboxylic acid) solutions used herein were identical to those used in Example 4.

Table V.

Pressue Applied (kg/cm^2)	P/L	Compressive Strength (kg/cm^2)
500	1.5	990
500	2.0	1,130
1,200	1.5	960

Comparative Example 1.

β-tricalcium phosphate (hereunder referred to as β-TCP) was prepared by calcining a mixture of β-calcium pyrophosphate and calcium carbonate by a conventional method, and hydroxyapatite (hereunder referred to as HAP) was also prepared by reacting calcium hydroxide with an aqueous phosphoric acid solution according to a conventional method. Each was kneaded with aqueous poly(carboxylic acid) solution (the same solution as that used in Example 4) and the compressive strength was measured on the resulting products as in Example 1. The results thus obtained are shown in Table VI.

Table VI.

Powder	P/L	Compressive Strength (kg/cm^2)
β-TCP	1.3	no hardening
HAP	1.3	30

As seen from the results listed in Table VI, β-TCP has no self-hardening property and HAP has a quite low compressive strength. Although the latter can be set, it cannot be put into practical use, because of its low strength.

Comparative Example 2

To a mixture of α-TCP (obtained in reference Example 1) and water, there was added a small amount of an inorganic acid or an organic acid and kneaded. The resulting product was subjected to the measurement of the compressive strength according to the procedure of Example 1. Table VII shows the results obtained.

Table VII.

α-TCP (g)	Water (g)	Acid Used	Amount thereof(ml)	Compressive Strength (kg/cm^2)
3	3.5	4N HNO_3	0.2	46
3	3.5	4N HCl	0.2	47
3	3.5	5% CH_3COOH	0.5	42
3	3.5	5% HCOOH	0.5	26

The results of Table VII show that all the cements thus obtained have low compressive strength of less than $50kg/cm^2$ and, as a result, these cements cannot be put into practical use.

CLAIMS

1. A surgical cement comprising:
a) a component (A) composed of at least one member selected from the group consisting of self-hardening α-tricalcium phosphate powder and self-hardening amorphous tricalcium phosphate powder;
b) a component (B) of surgically acceptable water-soluble poly(carboxylic acid); and
c) water.

2. A surgical cement according to claim 1, which comprises;
a) from 23 to 75% by weight of the component (A);
b) from 2 to 46% by weight of the component (B); and
c) from 10 to 69% by weight of water.

3. A surgical cement according to claim 1 or 2, in which the component (B) is in the form of an aqueous solution containing from 10 to 60% by weight of the component (B).

4. A surgical cement according to claim 3, which comprises;
a) component (A) and
b) an aqueous solution containing from 10 to 60% by weight of the component (B), the weight ratio of a) to b) being in the range of from 0.3:1 to 3.0:1.

5. A surgical cement according to any of the preceding claims, in which the self-hardening α-tricalcium phosphate powder is the powder obtained by compressing α-tricalcium phosphate under pressure, calcining it at a temperature of from 1,200 to 1,500°C for at least one hour and then pulverizing it into fine powder.

6. A surgical cement according to any of claims 1 to 4, in which the self-hardening α-tricalcium phosphate powder is the powder obtained by compressing amorphour tricalcium phosphate under pressure, calcining the pressed tricalcium phosphate at a temperature of from 1,200 to 1,500°C for at least one hour and then pulverizing it into fine powder.

7. A surgical cement according to any of the preceding claims, in which the poly(carboxylic acid) is a homopolymer of acrylic acid or a copolymer of (a) acrylic acid as principal monomer with (b) at least one unsaturated monomer selected from the group consisting of itaconic acid, maleic acid, fumaric acid, methacrylic acid, aconitic acid, citraconic acid, mesaconic acid, tiglic acid, and lower alkylesters thereof and lower alkylesters of acrylic acid.

8. A surgical cement according to any of the preceding claims, in which the poly(carboxylic acid) is a homopolymer of acrylic acid or a copolymer of (a) from 60 to 99.9% by weight of acrylic acid with (b) from 0.1 to 40% by weight of at least one unsaturated monomer selected from the group consisting of itaconic acid, maleic acid, fumaric acid, methacrylic acid, aconitic acid, citraconic acid, glutaconic acid, mesaconic acid, tiglic acid and lower alkylesters thereof and lower alkylesters of acrylic acid.

9. A surgical cement according to any of the preceding claims, in which the viscosity-average molecular weight of the poly(carboxylic acid) is in the range of from 2,000 to 200,000.

10. A surgical cement according to any of the preceding claims, which further comprises at least one other organic acid in an amount up to 10% by weight.

11. A surgical cement according to claim 10, in which said other organic acid is at least one member selected from the group consisting of glycolic acid, lactic acid, glutamic acid, pantothenic acid, tartaric acid, citric acid, malic acid.

12. A process for preparing a surgical cement which comprises preparing a mixture by admixing (a) a component (A) of at least one member selected from the group consisting of self-hardening α-tricalcium phosphate powder and self-hardening amorphous tricalcium phosphate and (b) a component (B) of a powdered surgically acceptable water-soluble poly(carboxylic acid), and adding a desired amount of water, or by adding an aqueous solution of component (B) to component (A); then kneading the mixture thus obtained to convert the mixture to a fluidized or plastic state.

13. A process according to claim 12, in which the amount of component (A) is in the range

of from 23 to 75% by weight, that of the component (B) is in the range of from 2 to 46% by weight and the water is used in an amount ranging from 10 to 69% by weight.

14. A process according to claim 12, in which the weight ratio of component (A) to the aqueous solution of component (B) is in the range of from 0.3:1 to 3.0:1.

15. A process according to any of claims 12 to 14, in which the self-hardening α-tricalcium phosphate powder has been obtained by compressing α-tricalcium phosphate powder under pressure, calcining the compressed α-tricalcium phosphate at a temperature of from 1,200 to 1,500°C for at least one hour and finely pulverizing the calcined product.

16. A process according to any of claims 12 to 14, in which the self hardening α-tricalcium phosphate is the powder obtained by compressing amorphous tricalcium phosphate powder under pressure, calcining the pressed tricalcium phosphate at a temperature of from 1,200 to 1,500°C for at least one hour and then finely pulverizing the calcined product.

17. A surgical cement substantially as herein described with reference to the Examples.

18. A process for preparing a surgical cement substantially as herein described with reference to and as illustrated in any of the Examples.

Printed in the United Kingdom for Her Majesty's Stationery Office, Dd 8818935, 1985, 4235.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.